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(57) Claim

1 A diffractive device having a surface relief structure which, when illuminated by a light source, generates one or more diffraction effects which are observable from a range of viewing angles around the device, wherein at least part of the surface relief structure is arranged in a series of tracks, each track being less than 0.25 mm in width.

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A DIFFRACTIVE DEVICE

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The following statement is a full description of this invention, including the best method of performing it known to applicant(s):

A DIFFRACTIVE DEVICE

This application is a divisional application of Australian Patent Application 59496/96, and the contents of the specification accompanying that application are hereby incorporated herein by reference

This invention relates to a diffractive device. It relates particularly to a diffractive device which, when illuminated by a light source, generates one or more diffraction effects which are observable from particular ranges of viewing angles around the device. The device may be used in a number of different applications, and it has particular applicability as an anti-forgery security device on banknotes, credit cards, cheques, share certificates and other similar documents

Several different types of diffractive devices which, when illuminated, generate diffractive images, are known. In January 1988, an Australian ten dollar banknote was released featuring a diffractive image of Captain Cook. The diffractive grating used in the image was for the most part comprised of substantially continuous lines, and the shapes and configurations of the lines were determined according to optical catastrophe theory in order to generate fine detail in the diffractive image observed

International patent application PCT/AU90/00395, the contents of which are incorporated herein by reference, discloses an alternative method for generating an optical diffraction image. In this case, the diffractive device is divided into a large number of small diffraction grating structures, each of which diffracts a beam of light which acts as a pixel, with the pixels combining to form an overall image. According to preferred aspects of the arrangement disclosed, the respective diffraction grating of each pixel comprises a plurality of reflective or transmissive grooves or lines which are usually curved across the pixel. Groove or line curvature determines both local image intensity (eg. shading) and local optical structure stability. Groove or line spacing in each pixel grating determines local colour properties, with non-primary colours generated by a pixel mixing. Average groove or line orientation determines movement or colour effects. The overall surface structure of each pixel grating is selected from a palette of

different grating types having a limited number of distinct values of average curvature and average spacing

An advantage of the use of pixel gratings in a diffractive device is that it permits the device to generate more than one diffraction image. Some of the gratings can have diffractive surfaces with particular line spacing curvature and orientation characteristics which contribute to the generation of an image viewable from a particular range of viewing angles, and other gratings have different surface characteristics contributing to the generation of a different image viewable from a different range of viewing angles. This result is much more difficult to achieve in a continuous grating diffractive device.

Another advantage of a pixel grating diffractive device is that it allows storage of picture information in a digital format. However, a predetermined surface area on the diffractive device must be set aside for each pixel, and this is not the most efficient way of storing picture information in a limited space. Accordingly, there is scope for a more efficient manner of storing picture information in a diffraction grating.

Moreover, in a pixel grating diffractive device, there are inevitable discontinuities between adjacent gratings. Diffraction effects occur in these discontinuities. It is normally possible to ensure these extraneous diffraction effects are small relative to the intentional diffraction effects generated by the diffractive device, but the extraneous diffraction effects are still detectable. It is desirable to reduce the extraneous diffraction effects

According to the present invention, there is provided a diffractive device having a surface relief structure which, when illuminated by a light source, generates one or more diffraction effects which are observable from different ranges of viewing angles around the device, wherein at least part of the surface relief structure is arranged in a series of tracks, each track being less than 0.25mm in width.

Tracks may be of any suitable shape, size and configuration. It is preferred that individual tracks have a length greater than 0.5mm. A width of 0.25mm represents approximately the limit of resolution of the human eye when viewing a diffractive device from close quarters, so that a track having a width of less than 0.25mm is unlikely to be separately discernible to the human eye.

The tracks may be in any suitable configuration. Tracks may constitute the whole or a majority of the surface relief structure, or they may constitute a small part of it only. In one preferred arrangement, the tracks are straight and parallel, in side-by-side configuration. In an alternative arrangement, the tracks may form arcs of concentric circles. In other arrangements, the tracks may be in the shape of curving lines.

In a preferred arrangement, each track has a diffracting surface which generates a component of a diffraction effect or image such that at least one of the diffraction images generated by the diffractive device is formed from image components generated by a plurality of the tracks.

In one arrangement in which two diffraction effects or images are generated, every second track contributes to one effect or image and every other track contributes to the other effect or image. It is not essential that all tracks be of the same width, but that is a preferred feature. It is not essential that the tracks for the two effects or images be arranged alternately; they may occur in any order. There may be more than two types of tracks, which may be associated with more than two effects or images.

In one preferred arrangement, the diffracting surface of each track comprises a series of lines or grooves which extend across the width of the track. As an alternative to lines or grooves, it is possible to use circles, polygons and other shapes which are capable of providing the required diffraction effects. In another preferred arrangement, the diffracting surface comprises a pattern of parallelogram-shaped indentations.

In another preferred arrangement, the diffracting surface of each track comprises a series of lines or grooves which extend in a generally lengthwise direction along the track. Such lines or grooves may be straight or curved, and in one arrangement they may be undulating periodically in a sinusoidal configuration. The lines or grooves may be short and discrete, or they may be substantially continuous throughout the length of the track.

In an especially preferred arrangement, the surface relief structure may include tracks having crosswise grooves or parallelogram patterns interspersed with tracks having lengthwise grooves or parallelogram patterns, such that diffraction effects from one set of tracks are observable when the diffractive

device is viewed in the direction of the tracks, and diffraction effects from another set of tracks are observable when the diffractive device is viewed perpendicular to the direction of the tracks.

The diffractive surface relief structure may be different in different portions of some or all of the tracks. The structure may vary along the length of some or all of the tracks, and/or it may vary across the width of some or all of the tracks. Such variations may be continuous or discontinuous. Thus, for example, some parts of the surface relief structure in a track may contribute to one observable diffractive effect, and other parts of the surface relief structure in the same track contribute to another observable diffractive effect.

In some arrangements, the orientation and spacing of the diffracting lines or other shapes on the surface of each track may vary continuously in terms of orientation, curvature and/or spacing along the track, the variations in orientation, curvature and/or spacing being the means by which image information is encoded into the tracks.

As an optional refinement, one of the images generated by the diffracting tracks may be a uniform or blank image which can be encoded with image information by the physical destruction or modification of regions of diffracting surface on selected tracks to produce corresponding diffusely reflecting regions.

The invention will hereinafter be described in greater detail by reference to the attached drawings which show an example form of the invention. It is to be understood that the particularity of the drawings does not supersede the generality of the preceding description of the invention.

Figure 1 is a schematic representation of a region of a surface relief structure on a diffractive device according to one embodiment of the present invention.

Figure 2 is a schematic representation of parts of the surface relief structure of Figure 1.

Figure 3 is a schematic representation of other parts of the surface relief structure of Figure 1.

Figure 4 is a more detailed schematic representation of two parts of tracks used in a diffractive device according to an embodiment of the present invention

Figure 5 is a detailed schematic representation of a part of two adjacent tracks in an alternative embodiment of the invention.

Figure 6 shows a schematic representation of a part of a track according to another embodiment of the invention.

Figure 7 shows a schematic representation of a part of two adjacent tracks according to an embodiment of the invention.

Figure 8 shows a computer-generated detailed representation of a section of two adjacent tracks according to an embodiment of the type shown in Figure 4.

Figure 9 shows a computer-generated detailed representation of a region of surface relief diffractive structure showing several tracks according to an embodiment of the type shown in Figure 5

Figure 10 is a computer-generated detailed representation of a part of two adjacent tracks according to another embodiment of the invention

Figure 11 is a computer-generated detailed representation of part of two adjacent tracks according to another embodiment of the invention.

Figures 12 to 25 are details of parts of surface relief structures according to example embodiments of the invention.

Referring firstly to Figure 1, part 1 of the surface relief structure is arranged in a series of tracks 2, each track having a diffracting surface 3 which generates a component of a diffraction image. In the embodiment illustrated, two separate images are generated, one by left hand side tracks 4, and one by right hand side tracks 5. The two diffraction images are formed from image components generated by individual tracks 4 and individual tracks 5 respectively.

Each of tracks 2 may be of any suitable length. It is preferred that each track be greater than 0.5mm in length, and for the sake of convenience, it is preferred that each track extend throughout the length of the diffractive device, although there is no requirement that this be the case. In the preferred embodiment illustrated, each of tracks 2 is straight and arranged in parallel side-by-side configuration. In alternative embodiments, the tracks may be arranged in concentric circles or sections of concentric circles, or in many other curved arrangements

Each of tracks 2 may be of any suitable width. It is preferred that the tracks be sufficiently narrow to be not noticeable to the naked human eye. The limit of

resolution of a normal human eye examining a diffractive device at close quarters is about 0.25mm. Accordingly, tracks having a width of less than this amount are unlikely to be separately discernible to the human eye.

As stated previously, discontinuities around the borders of individual pixels in pixellated diffracting devices result in incidental diffractive effects. The extent of such incidental effects is diminished by the use of tracks according to the present invention in that discontinuities along the length of the track can be avoided, although discontinuities are still present along the sides of each track.

It is preferred although not essential that each of tracks 2 be of the same width. If each track has the same width, the encoding of diffraction image data in the diffracting surface of each track is a simpler operation. However, in situations where it is desired that the diffractive device generate multiple diffraction images, it may be desired that one such diffraction image be brighter than another, and one way of achieving such an effect is to devote wider tracks to the generation of the bright image and narrower tracks to the generation of the dull image.

In the embodiment illustrated in Figure 1, tracks 2 are arranged substantially in side-by-side configuration. However, it is not essential that each track abut the next track, and a channel of any desired width may be left between adjacent tracks. It is sometimes advantageous to leave a small channel of about 4 micron in width between adjoining tracks to act as an air ventilation route during production of the diffractive device. Diffractive devices of the type herein described are typically manufactured by an embossing process, and it has been found that more satisfactory results are achieved if air ventilation can occur.

The diffracting surface on each of tracks 2 may have any suitable diffractive surface relief structure. In the embodiment illustrated in Figures 1 to 3, the surface relief structure comprises a series of curved or straight lines or grooves which extend across the width of the track. It is not essential that lines be used, and other suitable diffractive shapes include circles and polygons. In one suitable arrangement, the surface relief structure of a track may consist of variably shaped polygon structures having dimensions less than 1 micron positioned along and across each track in such a way as to encode the diffraction image information and diffractively regenerate it. In another embodiment, the surface relief structure of a track may consist of numerous diffracting dots of sizes

less than 0.25 micron, such that the diffraction image information is encoded in the spacing and distribution of the dots

Figure 4 illustrates in more detail portions of two tracks, each consisting of a complex generalized diffraction grating structure having grooves which vary continuously in terms of spacing, orientation and curvature along the length of the track. The variations in groove spacing, curvature and orientation are the means by which the diffraction image information is encoded in the tracks. In preferred arrangements, the variations in groove spacing, angle and curvature can be described by mathematical functions of two variables whose Hessian of second derivatives with respect to the two variables is non-vanishing except along certain characteristic lines within each diffracting track

One particular example of a suitable track grating function is given by the following expression:

$$Y = (\alpha - 2\pi(1.25\beta))Z - \frac{\beta}{\alpha - 2\pi(1.25\beta)} \cos(2\pi X) \cos(2\pi[\alpha - 2\pi(1.25\beta)]Z) \quad (1)$$

where,

- Z is the track groove index parameter.
- $\alpha = \alpha(Y)$ along the length of the track;
- $\beta = \beta(Y)$ along the length of the track;
- α is a preset variable which determines the local carrier wave frequency of the track and therefore determines the local line density of the track and the colour of the image component generated by the track. Typically, $0.8 < \alpha < 1.2$.
- β is a parameter which is set proportional to the local intensity of the colour of the track and determines the structural stability of the track. It is this parameter that is used to tune the image characteristics of the diffractive device. Typically, $0 \leq \beta \leq 0.056$;
- the number ranges of the local co-ordinates X and Y is given by $0 \leq X \leq 0.2$ and $0.2 \leq Y \leq 0.6$ for a left hand channel track, and $0.6 \leq X \leq 0.8$ and $0.2 \leq Y \leq 0.6$ for a right hand channel track; and
- the Hessian of the track grating is non-vanishing except along certain characteristic lines of the grating plane which, under gradient transformations,

map to lines of singularity (caustics) in diffraction space. The Hessian, $H(X,Y)$ of $Z(X,Y)$ is a standard complex derivative given by:

$$H(X,Y) = \frac{\partial^2 Z(X,Y)}{\partial X^2} + \frac{\partial^2 Z(X,Y)}{\partial Y^2} + 2 \frac{\partial^2 Z(X,Y)}{\partial X \partial Y} \quad (2)$$

Figure 4 shows two track segments having track grating functions of the type described in Equation (1) above. A single track may be comprised of several such segments linked end to end, each segment being of fixed or variable length. In arrangements where each track segment is of fixed length, it is preferred that each segment form a "period" in a "carrier wave" encoded into the track, with diffraction image information being encoded into each period by means of variation in groove spacing and curvature. The track segments illustrated in Figure 4 have a width of about 15 micron and a length of about 30 micron, although they can be scaled up or down in size as required.

Figure 8 is a computer-generated representation of a section of a pair of adjacent tracks, labelled 14 (left hand track) 15 (right hand track) channel. The track sections illustrated form part of a larger structure containing several left hand tracks interspersed between several right hand tracks. The left hand tracks, when illuminated, generate one or more diffraction images observable from particular positions around the diffractive device, and the right hand tracks generate images observable from different positions. The track portions illustrated are each about 15 micron in width and 60 micron in length.

As will be seen from close examination of Figure 8, each curved groove extending across the track is for the sake of convenience composed of eight segments 18, each of which is a parallelogram in shape. Each parallelogram indentation 18 is approximately two microns wide. Although most parallelograms 18 match up with neighbouring parallelograms to form curved grooves extending across the track, some add density to particular parts of the track surface without joining up with any neighbours.

The concept of dividing each groove into eight parallelograms 18 is taken a step further in the embodiment shown in Figure 10. In this embodiment, the track surface is comprised entirely of parallelogram-shaped indentations. The dark portions represent troughs, whereas the light portions represent crests. Some

parallelograms match up with their neighbours to form grooves but this is incidental rather than intentional as in the embodiment of Figure 8. In any line across one of the tracks in the embodiment of Figure 10, all parallelograms have the same angular orientation, whereas such orientation varies considerably in the embodiment of Figure 8.

The patterns shown in both Figure 8 and Figure 10 are used to generate pixels in the image planes. Each of the left-hand 14 and right-hand tracks 15 in each case includes two segments (16,17), the top half 17 being one segment and the bottom half 16 being another. Each segment generates one pixel. The patterns shown are used to generate pixels having one of sixteen different greyscale values. Segments with flatter lines produce darker pixels in the image plane, and segments with steeper lines (more sharply angled parallelograms) produce lighter pixels. A large number of track segments from different tracks can thus be used to generate a complete image with sixteen greyscales.

In addition to the 16 different types of greyscale segments, the "palette" of different track segment types in a preferred arrangement includes 10 different colour effects segments. The left hand track 14 in Figure 11 contains two colour effects segments (16,17). In the embodiment illustrated, colour effects segments are created using straight grooves which cross the track at right angles, with varying spatial frequencies. The right hand track 15 in Figure 11 contains two more colour effects segments but with grooves aligned with the track to create "90° effects" - that is, diffractive effects which are visible at positions 90° around from where the left hand track diffractive effects are visible.

An especially desirable type of colour effect is obtained when the colours appear to move along a path in the image plane when the diffractive device is tilted about an axis in its plane. Such effects can be obtained by sequential positioning of colour effects track segment types, with average spatial frequency increasing or decreasing along the sequence.

It is preferred that the colour effects track segments be modulated so that image components generated by those segments are observable over broader ranges of angles than they would have been if their diffracting surfaces were unmodulated. A suitable general modulation function is given by

$$y = ma + \beta F(Q = \frac{m}{N})$$

where β is a modulation factor; a is the average diffraction structure spacing; Q is the number of cycles of modulation; N is the total number of grooves or equivalent diffraction structures within the track segment; m is the groove index parameter ($m = 1$ to N), and F is sin or cos or another harmonic or quadratic function.

The spatial frequency of the vertical grooves of the right hand track in Figure 11 is the same at the top and bottom of each segment, and changes through several steps to a characteristic frequency in the centre 19 of each segment.

The right hand track 15 in Figure 10 has a different average spacial frequency from the left hand track 14 in order to reduce the likelihood of interference between the two different images which are to be generated. Moreover, the parallelograms 16 in the left and right tracks have opposing angular orientations.

Track surface patterns of the types illustrated in Figures 8, 10 and 11 are typically created using an electron beam. A 30 micron by 30 micron surface area is typically divided into a grid of 1024 by 1024 units. This grid is then used to define the start and end points of each parallelogram. In the embodiments shown in Figures 8, 10 and 11, one grid area covers one track segment (30 micron long) in each of two adjacent tracks (15 micron wide each). An algorithm, written in BASIC programming language, for generating the left hand track in Figure 10 is given by:

```
J1M&=JOM&+INT((45-3*(JJ-11))*ABS(SIN(1.5708*LLL/512))
```

```
*ABS(256-XINC)/1024)^1.5
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J1P&=JOP&+INT((45-3*(JJ-11))*ABS(SIN(1.5708*LLL/512))
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```
*ABS(256-XINC)/1024)^1.5
```

where JOP is the top left corner of a parallelogram

JOM is the bottom left corner

J1P is the top right corner

J1M is the bottom right corner

JJ is the number representing the type of greyscale element (JJ is between 11 and 26, giving 16 different types)

XINC = 64 (i.e. the width of the parallelogram, in grid positions)

LLL is a vertical index.

A similar algorithm applies for the right hand track in Figure 10

The diffracting tracks illustrated in Figures 8, 10 and 11 contain digitally encoded image information. That is, tracks are divided into segments of a predetermined size, and a portion of image information (usually corresponding with a single pixel in the image plane) is stored in each segment. It is not however necessary that tracks be divided into regular segments. Instead, the diffractive surfaces may vary continuously but irregularly in terms of diffractive structure spacing, curvature and orientation, so that image information can be stored in an analogue format rather than a digital format. In such an arrangement, the image in the image plane may be comprised of a group of lines (each line corresponding to a track) rather than a group of discrete pixels (each pixel corresponding to one or more track segments).

One or more of the diffracting tracks may contain diffusely reflecting regions (consisting of randomly spaced grooves) and/or specularly reflecting regions in between diffracting regions. Diffusely reflecting regions may be used to encode auxiliary information not found in the diffraction image. Specularly reflecting regions may be used to enhance the contrast properties of the diffracted image.

One or more diffraction images which are generated by the diffracting tracks may consist of abstract colour patterns which create variable colour effects which move along the tracks when the device is moved relative to the light source and the observer. In particular, the movement effect may be generated when the device is rotated about an axis in its own plane.

It is preferred that the diffracting tracks generate two or more diffraction images which are observable from different ranges of viewing angles around the diffractive device, with some of the diffracting tracks being devoted to producing each of the diffraction images. In the embodiment illustrated in Figures 1, 2 and 3, left hand tracks 4 are devoted to generating a first diffraction image which is observable from a first range of viewing angles around the diffractive device, and

right hand side tracks 5 are devoted to generating a second diffraction image which is observable from a second range of viewing angles around the diffractive device. As illustrated in Figure 1, the tracks are in an alternating right-left-right-left configuration; however, this is not necessary and the tracks may be arranged in any order, such as right-right-left-right-left-left.

Figure 5 shows sections of two tracks according to another embodiment of the invention. Left hand track 6 has grooves extending across the width of the track, generating diffractive images which can be observed from a direction generally along the length of the track. Right hand track 7 consists of a plurality of island regions 8 surrounded by flat regions 9. Island regions 8 have grooves extending lengthwise along the track, generating diffractive images which can be observed from a direction generally perpendicular to the length of the track. A particular advantage of the arrangement illustrated in Figure 5 is that diffraction images are generated both in the direction of the length of the tracks and in the perpendicular direction, so that the diffractive effects of the diffractive device are more readily observable.

Flat regions 9 are optional, but they provide certain advantages. As previously indicated, diffractive devices of the type described are typically created using an embossing process, and flat regions 9 act as vents for gas removal during the embossing process, resulting in a more precise finished product. Moreover, an electroplating process typically follows the embossing process, and flat regions 9 enable more accurate electroplating. Flat regions 9 may also carry printed lines which are responsive to the scan rates of particular colour photocopiers so that moire interference lines are created on a photocopied image of the diffractive device. Alternatively or additionally, flat regions 9 may be embossed or printed with micro-writing 13 having a size in the order of 2 micron as shown in Figure 9. Such micro-writing may serve as an additional security element and may include a registration number or other identifier unique to the diffractive device on which it appears, thereby enabling verification of authenticity by means of microscopic examination.

Left hand track 7, islands 8 and flat regions 9 may be of any suitable dimensions. In an especially preferred arrangement, left hand track 7 and island

regions 8 are each about 15 micron in width, and flat regions 9 are about 4 micron in width.

In a variation on the arrangement shown in Figure 5, each island 8 may be connected to its neighbouring islands by means of interconnecting grooves which may be branched, so that grooves are substantially continuous throughout the length of the track.

Figure 6 shows a track 10 having grooves which extend substantially along the length of the track rather than substantially across the track as is the case in the track segments of Figure 4. The diffraction effects generated by track 10 are substantially at right angles to those generated by a track comprised of track segments of the type shown in Figure 4. Track 10 essentially comprises "carrier waves", with image information being encoded into them by means of amplitude and groove spacing variations.

In some embodiments, the variations in groove spacing, angle and curvature can be described by mathematical functions of two variables whose Hessian of second derivatives with respect to the two variables is non-vanishing except along certain characteristic lines within each diffracting track, as previously discussed. However, this is not an essential condition, and in other embodiments the Hessian of second derivatives of the grating function may be identically zero for all points within the track.

Figure 7 illustrates schematically a combination of left and right tracks, 11 and 12 respectively. Left track 11 may be any one of the types of tracks illustrated in Figures 1, 2, 3, 4 and 8 and right track 12 is a track of the type shown in Figure 6. Several such left and right tracks may combine to form a two-channel diffractive device. Tracks 11 and 12 may be of any suitable width as previously discussed, and an especially preferred width is around 15 micron. The arrangement illustrated in Figure 7 is particularly advantageous because the image(s) produced by left tracks 11 will be observable from angles approximately 90° around from where the image(s) generated by right tracks 12 are observable.

In one embodiment of the invention, one or more of the images generated by the diffractive device may consist of a uniform or blank image plane which can be encoded with image information by the destruction or modification of diffracting elements at selected locations along selected diffraction tracks. This enables

post-production modification of the diffracting device to incorporate a new diffraction image, although the resolution of the image information so incorporated is lower than the resolution normally provided by a diffracting track. A particular embodiment of this feature comprises a series of tracks. Along the length of each track, the diffracting surface alternates between surface portions which give rise to black image components in the image plane and surface portions which give rise to white image components. In order to create a dark area in the image plane, the "white" parts of the corresponding diffracting surface portions are erased; whereas the "black" surface portions are erased to create a bright area. In this way it is possible to encode a black-and-white bit image into the tracks.

As a further enhancement, the diffracting surfaces on some of the tracks may include diffusely reflecting regions. Such regions do not affect the images observed in the image phase, but they give a neutral background appearance to the diffractive device, making the images more easily observable.

As another enhancement, some of the tracks may include specularly reflecting regions. Such regions are useful in adding contrast to the images observed in the image planes.

Figure 12 shows a pair of tracks according to the present invention featuring straight line grooves oriented longitudinally along the track for the left track and horizontally across the track for the right track.

Figure 13 shows a typical structure incorporating several pairs of tracks of the type shown in Figure 12. The diffracting grooves in this case are straight line grooves and not continuously varying grooves of the type previously described. As a result, the image component generated by each track is substantially uniform.

Figure 14 shows four track sections according to an embodiment of the present invention, with each section being separated from the next by a specularly reflecting or "gloss" area. The first and third tracks contain grooves which are oriented longitudinally of the tracks, and the second and fourth tracks contain grooves which are oriented obliquely. In this arrangement, the first and third tracks contribute components to one image, and the second and fourth tracks contribute components to another image.

Figure 15 shows five track segments. The first and fourth tracks have grooves oriented longitudinally; the second and fifth tracks have grooves oriented obliquely, and the third track has grooves oriented transversely. This arrangement results in three different images being visible from three different ranges of viewing angles around the diffractive device.

Figure 16 shows a combination of tracks designed to generate images of a musical note at two different locations separated from each other by approximately 90° . The tracks with longitudinally aligned grooves contribute to one of the images, and the tracks with transversely aligned grooves contribute to the other image.

Figure 17 shows another arrangement in which one track is entirely encompassed, and forms an island, within another track. Arrangements of this type can be useful in creating components of images, particularly if the dimensions of the track exceed 0.25mm and thereby become visible.

Figure 18 shows pairs of tracks suitable for forming parts of a geometrical figure which is observable from two different ranges of viewing angles separated from each other by 90° .

Figure 19 shows various track sections separated from each other by specularly reflecting surfaces, combining to form a geometrical figure in the image plane.

Figure 20 shows an arrangement of various pairs of tracks separated by specularly reflecting tracks and demonstrating that the precise order of arrangement of tracks over a small area does not significantly alter the images observed in the image plane.

Figure 21 shows an arrangement in which the boundaries between adjacent tracks are not straight. The straightness of tracks, in the main, significant only for convenience in construction, the borders of tracks may be curved or irregularly shaped in order to provide a means for encoding diffracted light intensity variation along each track.

Figure 22 illustrates that individual tracks may be curved, and they may curve around on themselves and include acute and oblique angles without significantly detracting from the images produced by the diffractive device.

Figure 23 illustrates that the boundaries between adjoining tracks may be irregular without being curved, as another means of encoding diffracted light intensity variations along each track.

Figure 24 shows further possible shapes for tracks, with the diamond shape shown being particularly suitable for creating a diamond shape in the image planes, with separate diamond shapes being created in separate image planes according to the orientation of the grooves on the diffracting tracks.

Figure 25 shows another possible arrangement in which a series of track islands is located in a track sandwiched between two other tracks, with each track island being separated from the next by a gloss area of the track.

It is to be understood that various alterations, additions and/or modifications may be incorporated into the parts previously described without departing from the ambit of the present invention.

The claims defining the invention are as follows:

1. A diffractive device having a surface relief structure which, when illuminated by a light source, generates one or more diffraction effects which are observable from a range of viewing angles around the device, wherein at least part of the surface relief structure is arranged in a series of tracks, each track being less than 0.25 mm in width.
2. A diffractive device according to claim 1 wherein adjacent tracks cannot be separately discerned by the normal human eye.
3. A diffractive device according to claim 1 or claim 2 wherein the majority of the surface relief structure consists of tracks.
4. A diffractive device according to any one of claims 1 to 3 wherein each track has a diffracting surface which generates a component of a diffraction effect such that at least one of the diffraction effects generated by the diffractive device is formed from image components generated by a plurality of the tracks.
5. A diffractive device according to any one of claims 1 to 4 wherein the tracks are greater than 0.5 mm in length.
6. A diffractive device according to any one of claims 1 to 5 wherein the tracks are substantially straight and parallel, and extend throughout the length of the diffractive device.
7. A diffractive device according to any one of claims 1 to 6 wherein each member of a first group of the tracks has a similar first structure and contributes to a first diffraction effect, and each member of a second group of the tracks has a second structure different from the first structure and contributes to a second diffraction effect.

8. A diffractive device according to claim 7 wherein tracks of the first group and tracks of the second group alternate.

9. A diffractive device according to claim 7 wherein some of the tracks of the first group are directly adjacent to other tracks of the first group and some of the tracks of the second group are directly adjacent to other tracks of the second group.

10. A diffractive device according to any one of claims 1 to 8 for use as an anti-forgery device on bank notes, credit cards, cheques, share certificates or other similar documents.

11. A metallised foil bearing a diffractive device according to any one of claims 1 to 10 which is suitable for application to a valuable document.

12. A method of protecting a valuable document, comprising applying to the document a diffractive device according to any one of claims 1 to 10.

13. A method according to claim 9 wherein the diffractive device forms a security region on the valuable document.

14. A diffractive device according to any one of claims 1 to 10 wherein the diffractive surface relief structure is different in different portions of some or all of the tracks.

15. A diffractive device according to claim 14 wherein the diffractive surface relief structure varies along the length of some or all of the tracks.

16. A diffractive device according to claim 14 or claim 15 wherein the diffractive surface relief structure varies across the width of some or all of the tracks.

17. A diffractive device according to claim 15 wherein the orientation of diffractive structural elements varies continuously or discontinuously along some or all of the tracks.

5 18. A diffractive device according to claim 16 wherein the orientation of diffractive structural elements varies continuously or discontinuously across some or all of the tracks.

10 19. A diffractive device according to any one of claims 14 to 17 wherein some parts of the surface relief structure in a track contribute to one observable diffractive effect, and other parts of the surface relief structure in the same track contribute to another observable diffractive effect.

15 DATED : 3 October, 1997

PHILLIPS ORMONDE & FITZPATRICK

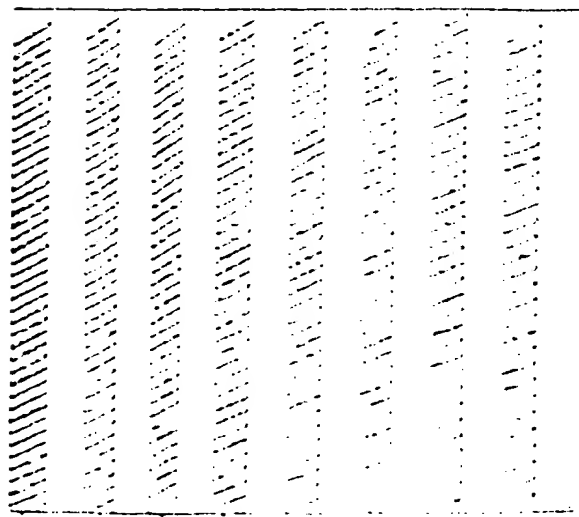
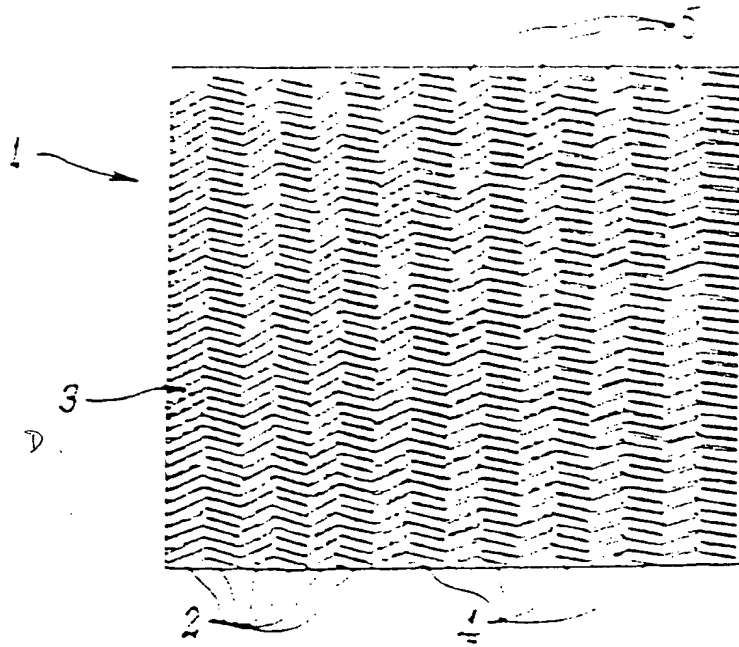
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ABSTRACT

A diffractive device having a surface relief structure which, when illuminated by a light source, generates one or more diffraction effects which are observable from a range of viewing angles around the device, wherein at least part of the surface relief structure is arranged in a series of tracks, each track being less than 0.25 mm in width.



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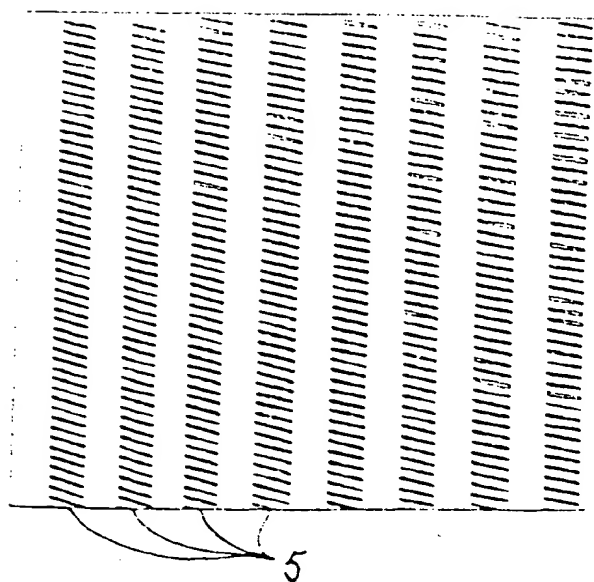


FIG 3

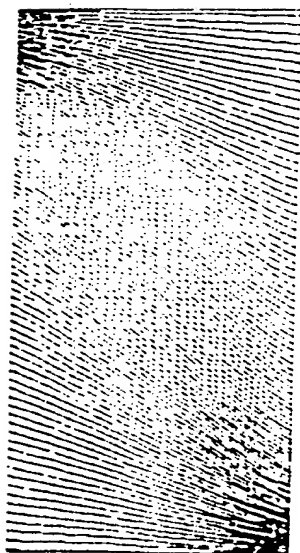
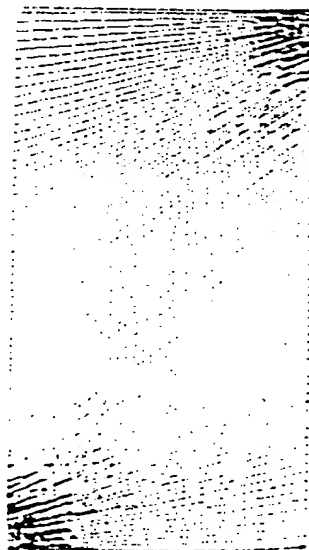


FIG 4



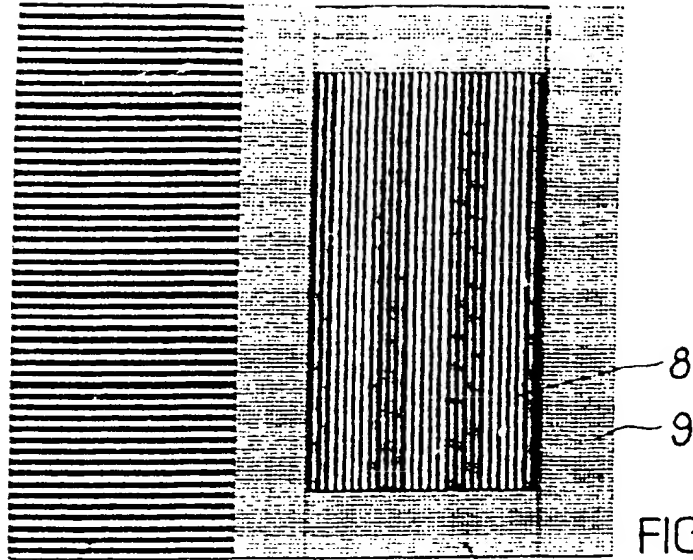
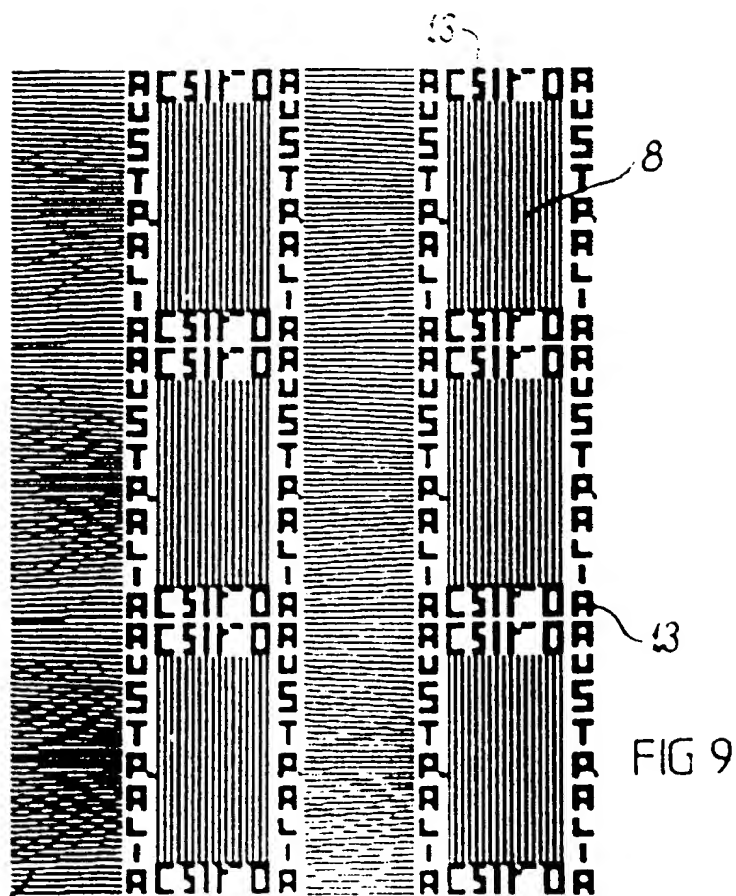
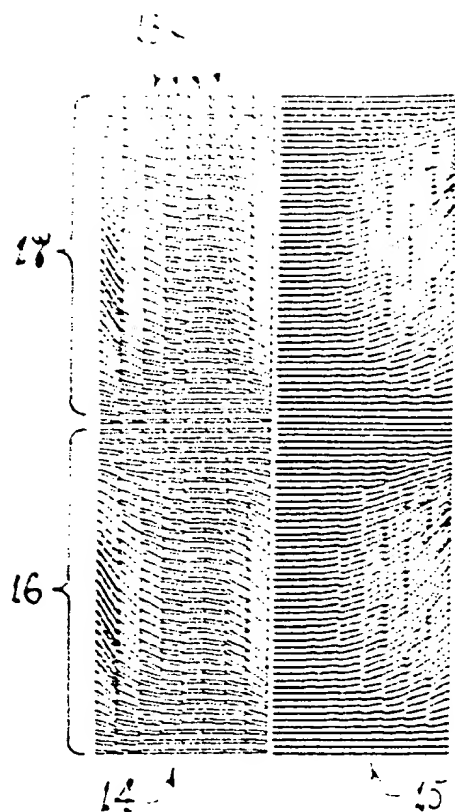
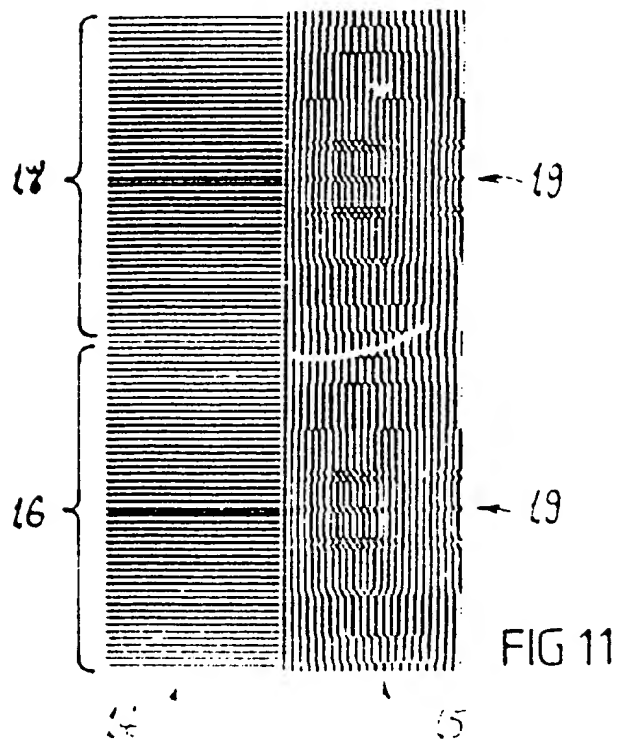
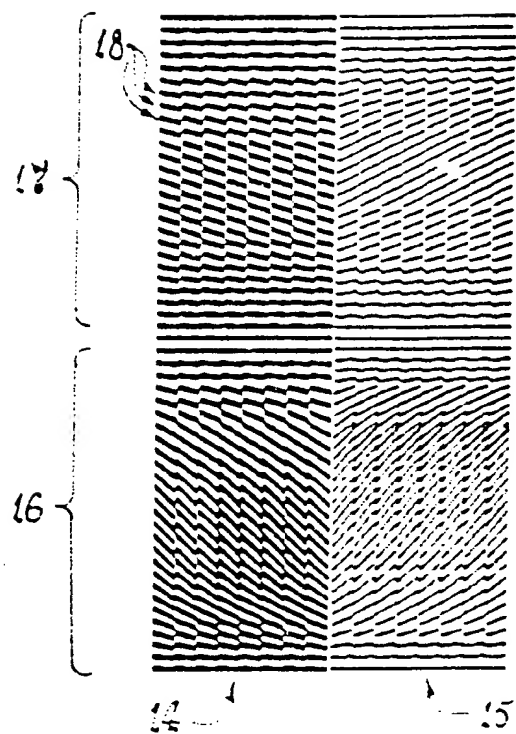


FIG 5

FIG 7





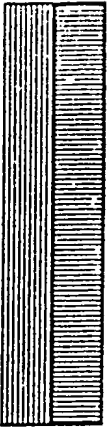


FIG. 12

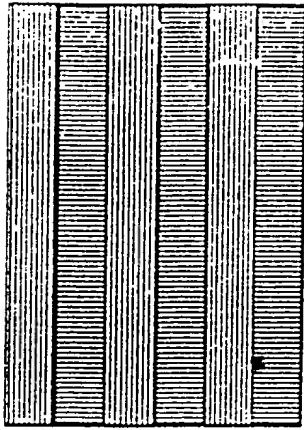


FIG. 13

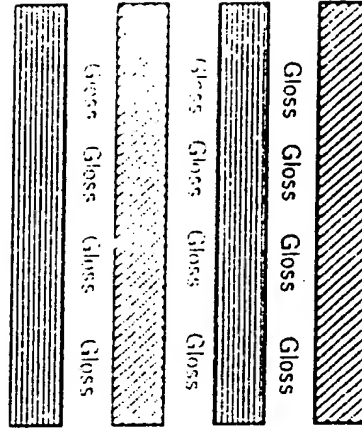


FIG. 14

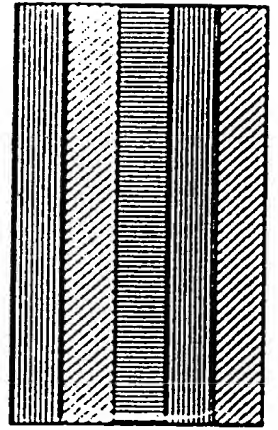


FIG. 15

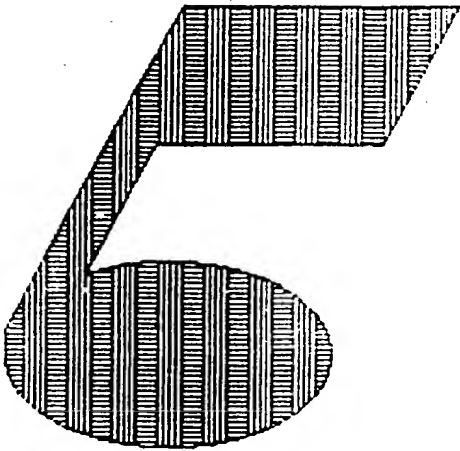


FIG. 16

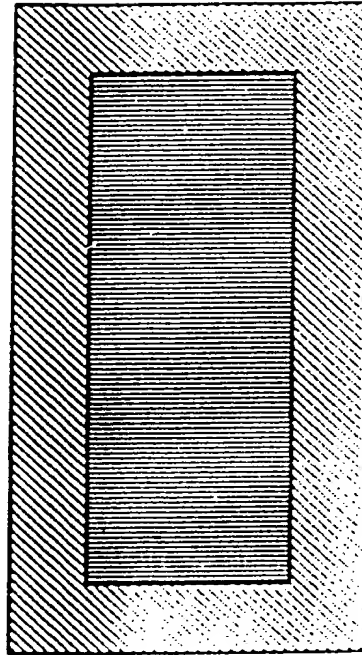


FIG. 17

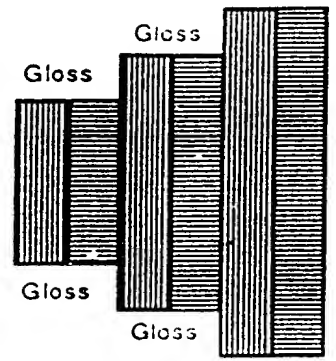


FIG. 18

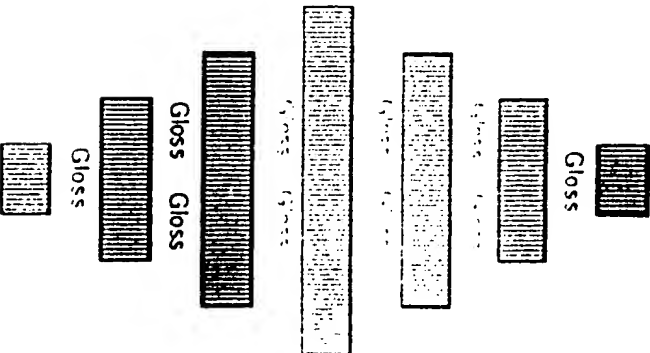


FIG. 19

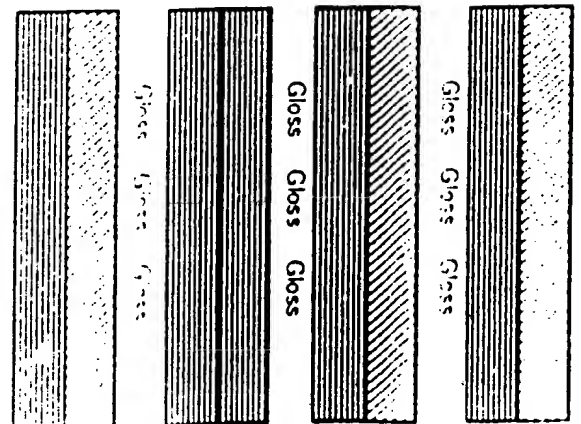


FIG. 20

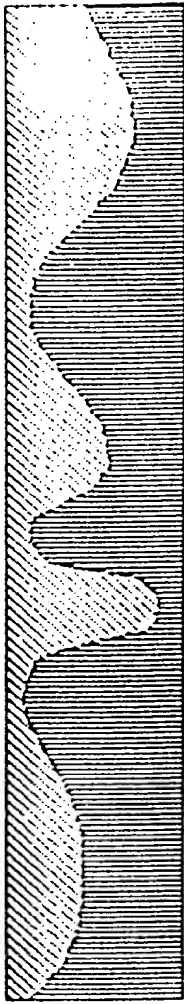


FIG. 21

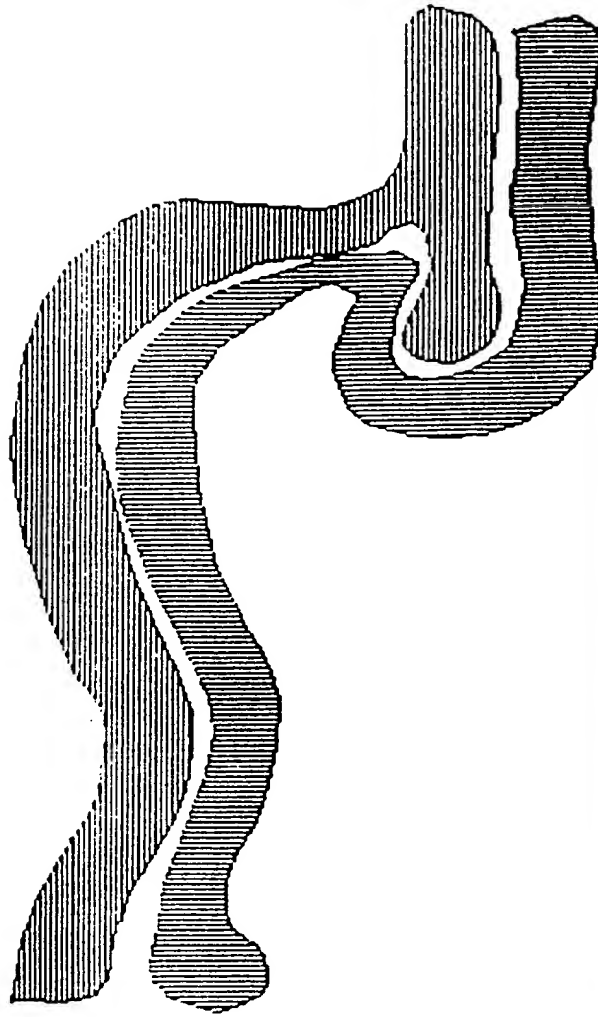


FIG. 22

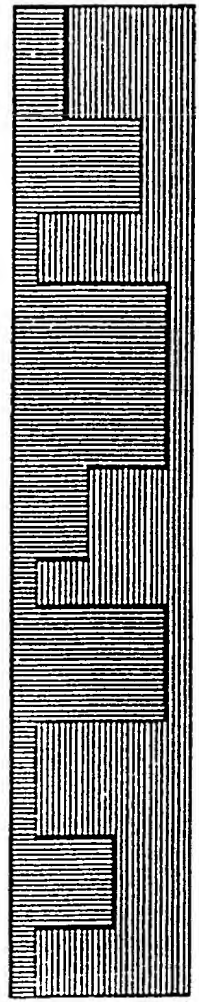


FIG. 23

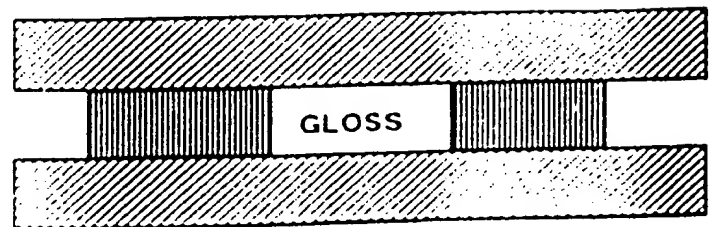
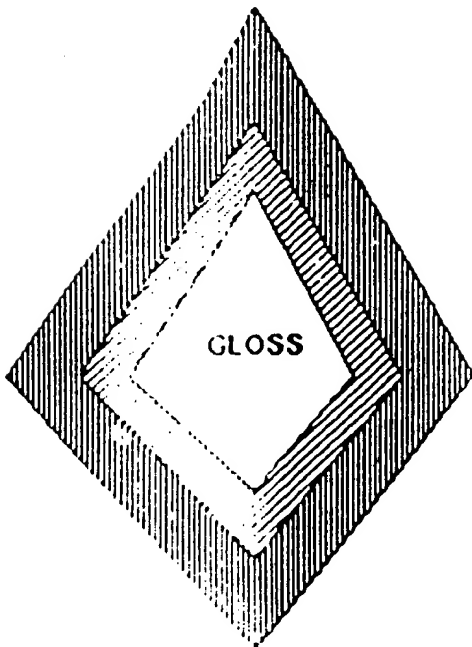


FIG. 25